蝶と蛾 *Trans. lepid. Soc. Japan* **48** (4): 223–233, November 1997

Seasonal occurrence of the chestnut tiger butterfly, *Parantica sita* (Lepidoptera: Danaidae), at 3 habitats in the Kii Peninsula, central Japan

Norio HIRAI[1] and Minoru ISHII

Entomological Laboratory, College of Agriculture, Osaka Prefecture University, Sakai, Osaka, 593 Japan

Abstract A rearing experiment on the chestnut tiger butterfly, *Parantica sita* (Lepidoptera, Danaidae), was made under a photoperiod of 12L-12D or 16L-8D at 15, 20 or 25°C. Mean egg, larval and pupal stages were about 5, 7 and 12; 18, 23 and 40; and 10, 15 and 27 days, at 25, 20 and 15°C, respectively, and they had not entered diapause under any conditions. It takes 2 weeks for half of the females to mature eggs even at 25°C. Field researches were also made in 3 habitats of *P. sita* in the Kii Peninsula. Esuzaki (alt. about 20 m), on the south coast facing the Pacific Ocean, was used mainly by the overwintering generation and few individuals were seen between spring and autumn. At Yamada (alt. about 360 m), at the southern foot of the Izumi Range, individuals of immature stages were seen on the evergreen milkweed, *Marsdenia tomentosa* (Asclepiadaceae). At the study site of Mt Wasamata (alt. 1,100 m), on the eastern slope of the mountain, lots of adults were seen from July to August and a few eggs and larvae were also seen on the deciduous milkweed *Cynanchum caudatum* (Asclepiadaceae), in the summer season. The number of generations of the 3 habitats estimated from effective accumulative temperatures of each habitat could not explain the actual occurrence of each habitat. This may be because of the high migratory nature of this species.

Key words *Parantica sita*, migration, seasonal occurrence, developmental threshold, thermal constant, Kii Peninsula, Japan.

Introduction

It has become known that the chestnut tiger butterfly, *Parantica sita* (Moore), migrates sometimes over 1,000 km from southwest to northeast or lowland to highland in spring, and *vice versa* in autumn by the mark-release-recapture studies in Japan (Fukuda, 1991). Lots of records and reports on the biology of this species in the field have been published (*e.g.* Kanazawa *et al*., 1993), although most of them were fragmentary and there were few studies on the population dynamics in the field.

Recently, we reared *P. sita* in the laboratory and also made field researches in 3 habitats of *P. sita* in the Kii Peninsula, where the altitude, climate and vegetation are varied, to estimate the number of generations there.

Materials and methods

Rearing experiment

Eggs of *P. sita* were obtained from 11 females captured in Nara, Wakayama and Osaka Prefectures, from 1992 to 1994. Larvae were reared individually in 200-ml clear plastic cups

[1] Present address: Soma Branch, Fukushima Prefecture Agricultural Experiment Station, Soma, Fukushima 979-25, Japan

for the 1st–4th instars and 400-ml ones for the 5th instar under a photoperiod of 12L-12D or 16L-8D at 15, 20 or 25°C. Fresh leaves of the evergreen climber milkweed, *Marsdenia tomentosa* (Asclepiadaceae) collected at Yamada, Hashimoto City, in northern Wakayama Prefecture were supplied. We recorded egg, larval and pupal stages individually.

We reared emerged adult females by feeding them on 10% sugared water under the same condition as that for the larval stage and dissected their abdomens 0, 3, 7 or 14 days after emergence to observe if they had mature eggs or not. We defined mature eggs as those with a height of about 1.6 mm and longitudinal ribs on the surface.

From the relationship between temperature and developmental velocity in egg, larval and pupal stages and the period from oviposition to adult emergence, developmental thresholds t_0 and thermal constants (K) were calculated. Using these values and the decade mean temperature of AMeDAS (Automated Meteorological Data Acquisition System), we estimated the number of generations of *P. sita* at Esuzaki, Yamada and Mt Wasamata. We used the AMeDAS data of Shionomisaki, Katsuragi and Kamikitayama for Esuzaki, Yamada and Mt Wasamata, respectively. Moreover, we corrected the temperatures of the latter two habitats according to the altitude (−0.6°C/100 m)

Field research

We made field researches at 3 sites, Esuzaki, Yamada and Mt Wasamata, known as habitats of *P. sita* in the Kii Peninsula to document the seasonal fluctuation of the population density from May, 1993 to March, 1995 (Fig. 1). The study site of Esuzaki (alt. about 20 m), on the south coast of the Kii Peninsula facing the Pacific Ocean in southern Wakayama Prefecture, was covered with a broad-leaved evergreen forest, predominantly by *Castanopsis sieboldii*, *Quercus phillyraeoides*, *Camellia japonica*, etc. (Fig. 2). The study site of Yamada, at the southern foot of the Izumi Range (alt. about 360 m) in northern Wakayama Prefecture, was covered with a plantation of Japanese cedar and cypress with the shrubs *Aucuba japonica*, *Cam. japonica*, *Neolitsea serice*, etc. (Fig. 3). The study site of Mt Wasamata (alt. about 1,100 m) located on the eastern slope of the mountain (alt. 1,344 m) in southern Nara Prefecture was covered with broad-leaved deciduous forests predominantly by *Fagus crenata*, *Quercus crispula*, etc. and with grasslands of Japanese pampas grass, *Miscanthus sinensis* (Fig. 4).

We made observations once a month as a rule from May, 1994 to May, 1995 at Esuzaki, from May, 1993 to March, 1994 at Yamada and from May to October, 1993 and 1994 at Mt Wasamata, respectively. We settled census routes of about 500 and 300 m at Esuzaki and Yamada, respectively, and counted the numbers of eggs, larvae and pupae of *P. sita* observed on the leaves of *M. tomentosa* growing along the route. At Mt Wasamata, we recorded the number of adults seen along the route of about 600 m. Since there was no *M. tomentosa* in the study site of Mt Wasamata, we put 5 potted plants (7 stocks) with a total of 50 leaves from Yamada on the forest floor near the forest edge where lots of adults were seen in summer.

Results

Estimated numbers of generations at 3 habitats

Mean stages of egg, larva and pupa decreased significantly ($p<0.05$ by Tukey-Kramer test) with ascending temperature, but no arrested development was observed at any temperature or photoperiodic conditions (Table 1). Mean egg, larval and pupal stages were about 5, 7 and

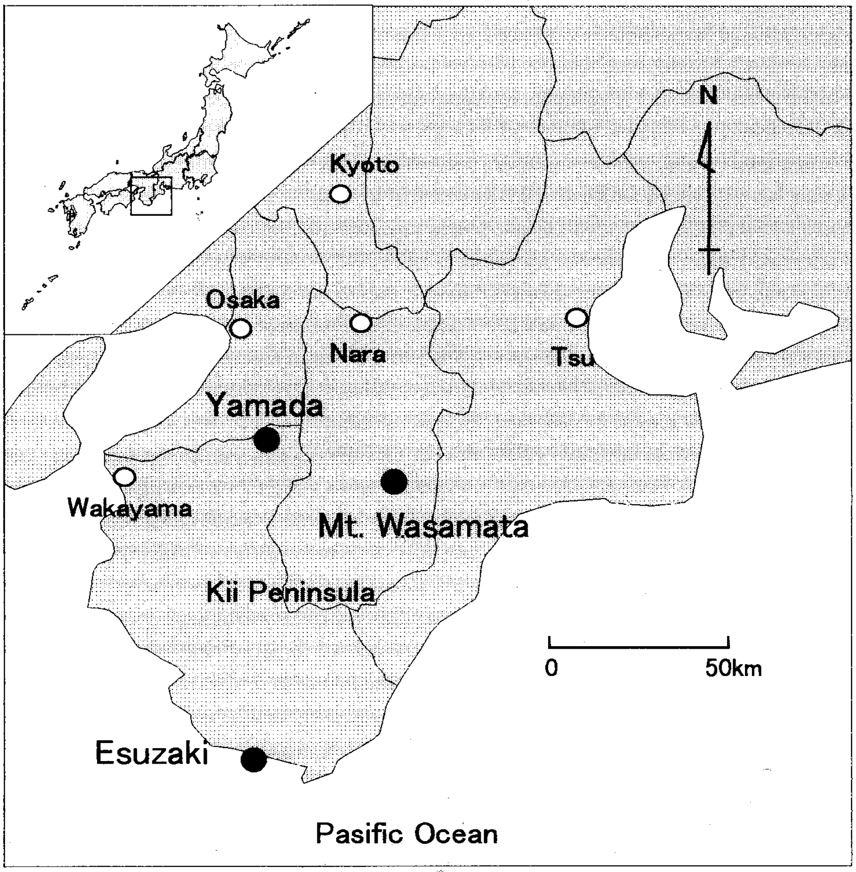


Fig. 1. Location of 3 study sites of *Parantica sita* in the Kii Peninsula.

12; 18, 23 and 40; and 10, 15 and 27 days, at 25, 20 and 15°C, respectively, and all individuals passed 5 larval instars before pupation. The mean total immature stage, *i.e.* the stage from oviposition to adult emergence, was about 35, 44 and 80 days at 25, 20 and 15°C, respectively. The regression lines for temperature and developmental velocity, t_0s and Ks for egg, larval, pupal and total immature stages under 12L-12D and 16L-8D are shown in Fig. 5 and Table 2. The t_0 and K for the total immature stage were 6.1°C and 637 day-degrees, respectively.

Table 1. Mean egg, larval, pupal and whole immature stages (egg–pupa) of the chestnut tiger, *Parantica sita*, under different temperature and photoperiodic conditions.

Condition		Mean stage±SD (days)				n
		Egg	Larva	Pupa	Egg-Pupa	
15°C	12L-12D	12.2±1.0a	40.6±2.5a	27.0±1.0a	79.4±3.0a	46
	16L- 8D	—	39.2±1.6a	27.7±1.5a	—	17
20°C	12L-12D	7.5±1.4b	23.7±2.3b	15.1±1.6b	46.3±4.1b	49
	16L- 8D	6.7±1.1c	21.5±2.0c	15.0±1.1b	42.2±2.1c	43
25°C	12L-12D	5.4±1.8d	18.5±2.3d	10.7±0.8c	34.6±2.6d	52
	16L- 8D	5.4±0.7d	18.2±1.8d	11.1±0.9c	34.5±2.4d	46

Means followed by the same letter in the column are not significantly different at 5% levels by Tukey-Kramer test.

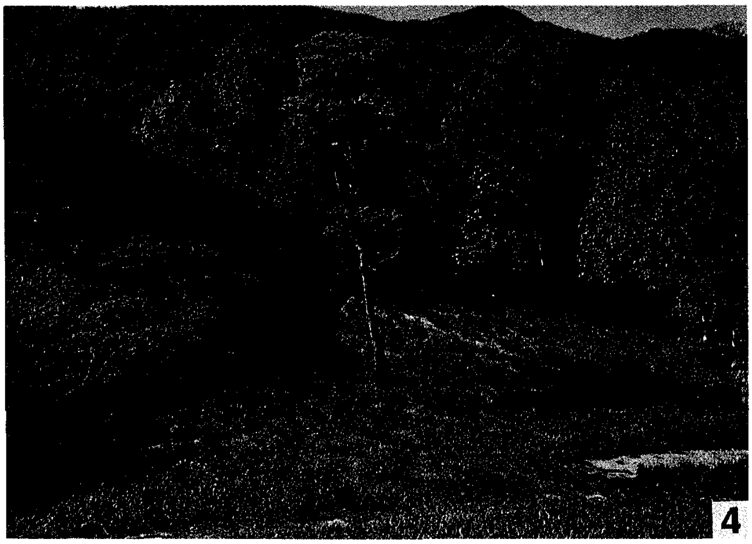


Fig. 2. Study site of Esuzaki (alt. about 20 m), Susami Town, Wakayama Prefecture.
Fig. 3. Study site of Yamada (alt. about 360 m), Hashimoto City, Wakayama Prefecture.
Fig. 4. Study site of Mt Wasamata (alt. about 1,100 m), Kamikitayama Village, Nara Prefecture.

Table 2. The regression lines of the developmental velocity (V), developmetal threshold (t_0) and thermal constants (K) calculated by relations between temperatures (t) and developmental velocities of eggs, larva, pupa, and total immature stages of *Parantica sita*

Stage	Regression line	r	t_0 (°C)	K (day-degrees)	n
Egg	$V=-0.0697+0.0106t$	0.72***	6.6	94.5	219
Larva	$V=-0.0172+0.00295t$	0.92***	5.8	339.3	253
Pupa	$V=-0.0435+0.00545t$	0.96***	8.0	183.4	253
Egg-Pupa	$V=-0.0950+0.00157t$	0.94***	6.1	636.9	219

Since effective accumulative temperatures for *P. sita* were calculated as 3,973 and 4,354 day-degrees at Esuzaki in 1993 and 1994, respectively, it is inferred that 6 generations would occur there. Effective accumulative temperatures at Yamada and Mt Wasamata were calculated as 2,755 and 3,195, and 1,404 and 1,865 day-degrees in 1993 and 1994, respectively, so that numbers of generations were estimated as 4–5 and 2–3 at the former and latter habitats, respectively.

Ovarian developments

No females had mature eggs at the adult eclosion (n=1) and 3 days after then (n=2), respectively. Although only 4 females (31%) in 25°C-16L-8D had mature eggs a week after emergence, mature females were also observed at 25°C-16L-8D and -12L-12D, and 20°C-12L-12D two weeks after emergence (Table 3). However, no female had mature eggs in 20°C-16L-8D and the rate of mature females was lower in 20°C-12L-12D than in 25°C-12L-12D even 2 weeks after emergence. It seemed that the ovarian development was delayed by lower temperature in this species. Moreover, the rate of mature females were about 50 % at 25°C even 2 weeks after emergence, which suggests that it takes about a month for all females to mature eggs even at 25°C.

Seasonal occurrence at 3 habitats

Fig. 6 shows numbers of eggs and larvae of *P. sita* per 1,000 leaves of *M. tomentosa* (Fig. 7) at Esuzaki and Yamada, and the number of adults seen per hour at Mt Wasamata.

At Esuzaki, we examined 559 leaves of *M. tomentosa* at an observation on the average. Eggs of *P. sita* were found in August, October and November, and 1st–3rd instar larvae resulting from these eggs were seen in August and from October to February. Forth and 5th (final) instar larvae were seen from December to March (Fig. 8). Adults were seen on July 27 (1 ♂) and August 30 in 1994 (2 ♀), and on May 6 in 1995 (1 ♀ and 1 *ex*.).

Table 3. Numbers (%) of *P. sita* females with mature eggs 7 and 14 days after adult emergence

Condition		7 days	n	14 days	n
20°C	12L-12D	0 (0%)	9	2 (22%)	9
	16L- 8D	0 (0)	10	0 (0)	6
25°C	12L-12D	0 (0)	9	5 (56)	9
	16L- 8D	4 (31)	13	4 (50)	8

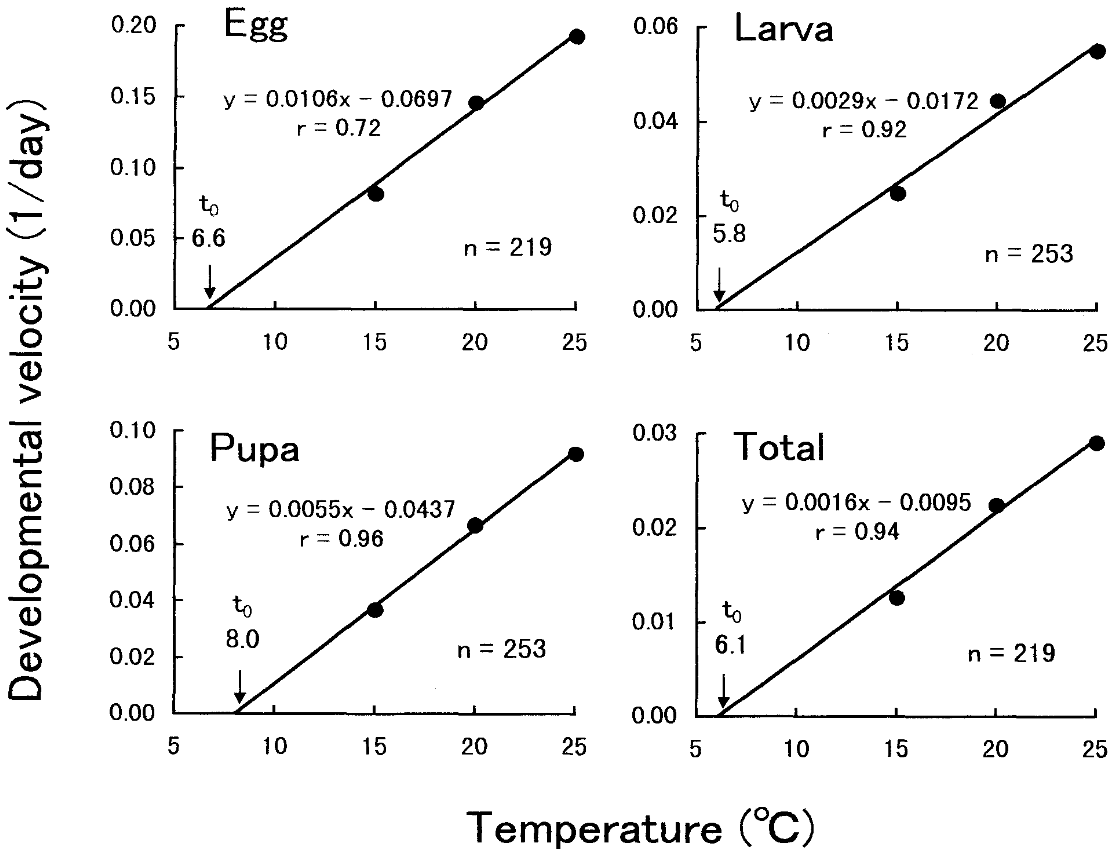


Fig. 5. Relationships between temperature and developmental velocity in egg, larval, pupal and egg to pupal stages of *Parantica sita*. Regression lines and sample sizes are shown in figures.

At Yamada, the mean number of *M. tomentosa* leaves examined per an observation was 712. Eggs were seen from June to October in 1993, and in June, August, September and November 1994. We found eggs on *M. tomentosa* at a distance of about 50 m from the census route in October 1994, although no egg was observed along the route. In both years, 3–4 peaks of oviposition were observed, and 1st–3rd instar larvae were seen from June to September with the highest density in June. In the overwintering generation, after the density of 1st–3rd instar larvae decreased gradually, from November 1993 to April 1994 and from November 1994 to March 1995, 4th and 5th instar larvae were sometimes seen although the density was low. Some pupae including ones parasitized by the tachinid, *Sturmia bella*, were found in July, September, October and November in 1993 and from May to December in 1994. Adults were seen on August 8 (1 ♀), September 4 (1 ♀) and October 4 (1 ♀). We also found adults on October 17 (3 ♀ and 1 *ex.*) in 1994 although it was outside of our regular research.

At Mt Wasamata, the mean number of leaves of potted *M. tomentosa* was 60 and we found 7 eggs and a single 3rd instar larva in late August and mid September, respectively. Although we did not make regular observations on the deciduous climber milkweed, *Cynanchum caudatum* (Asclepiadaceae) (Fig. 9), one of the food plants of *P. sita* and growing along the route, we found eggs in June in 1993 and in May, August and September in 1994 (Fig. 10). We also found 1st–3rd instar larvae on the plant in August and 3rd instar

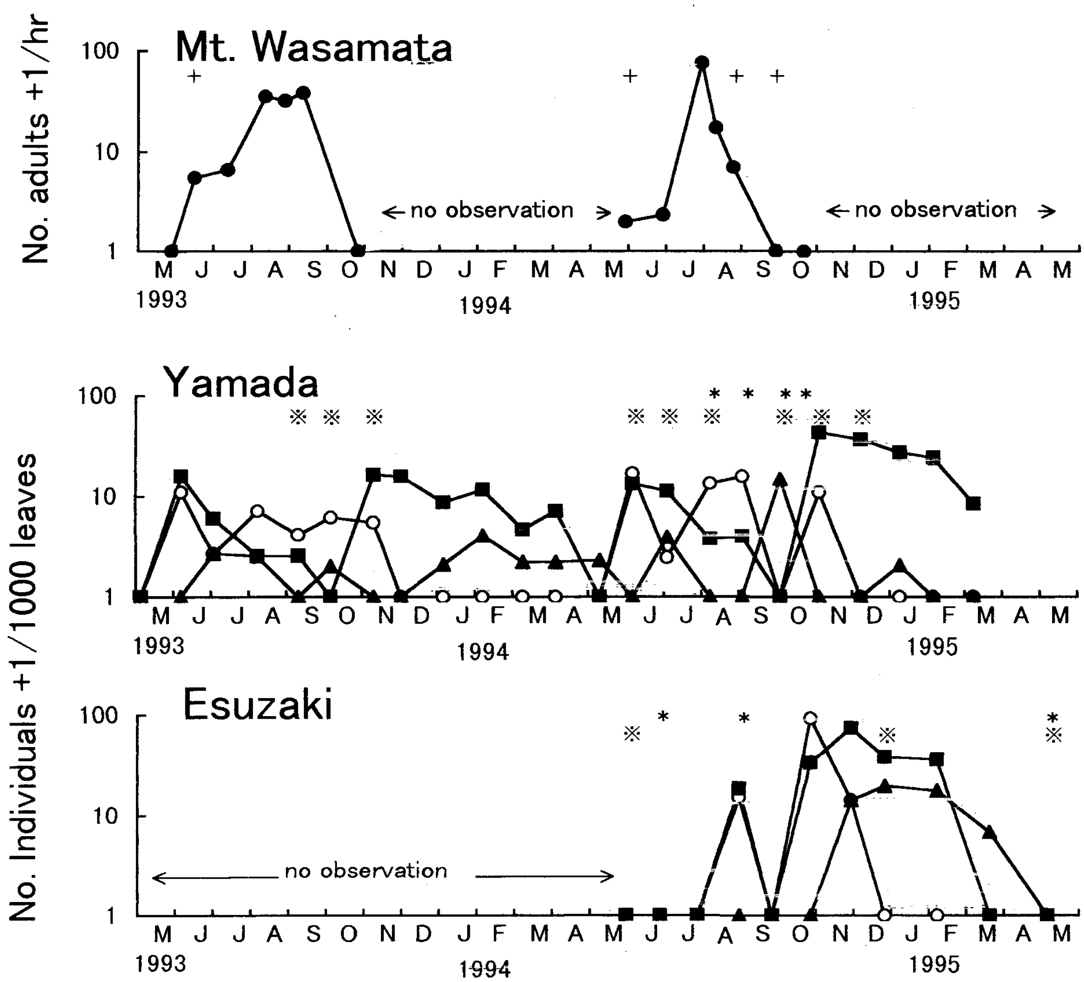


Fig. 6. Seasonal prevalence of eggs (○), 1st–3rd instar larvae (■), 4th and 5th instar larvae (▲) and adults (●) of *Parantica* sita in the 3 habitats, Mt Wasamata, Yamada and Esuzaki. The day when eggs or larvae (+), pupae or those parasitized by the tachinid, Sturmia bella (※), and adults (＊) observed were shown in the figure.

ones in September in 1994. Average time needed for the adult census was 1.4 hour and lots of adults were observed along the census route from June to September in 1993 and from May to September in 1994 (Fig. 11). Numbers of adults observed per hour reached peaks in August in 1994 and in late July in 1994. Many of them were visiting the flowers of *C. candatum* or *Eupatorium makinoi* growing along the route to take nector.

Discussion

Overwintering stage

It has been shown by our field research that larvae were seen continuously developing and transforming into pupae even in winter at Esuzaki and Yamada. Watanabe and Jinbo (1968) also reported that 1st–3rd instar larvae of *P. sita* overwintered at a high survival rate in Shizuoka Prefecture. Overwintering at early larval instars was also observed in the Inunaki Valley located at the northern foot of the Izumi Range in southern Osaka Prefecture (alt. about 200 m) (Chestnut-Tiger Research Group, 1986*a*) and Mt Tenjin (alt. 455 m),

Nara Prefecture (Chestnut-Tiger Research Group, 1986*b*). According to Fukuda (1991), there have been some records in which pupae of this species could overwinter in such habitats where the winter is mild as Shikoku and Kyushu Islands. In this study, we obtained results in which *P. sita* shows no arrested development in any immature stages under any conditions tested. These observations and our results of rearing experiments may show that this species has no fixed overwintering stage.

In the monarch butterfly, *Danaus plexippus*, the ovarian development of adult females is delayed during the winter (Barker and Herman, 1976). As for *P. sita*, there have been no records in which adults overwinter in the south and return to the north in spring, and our rearing experiments show that no arrest of ovarian development occurs in female adults under the short day conditions. Therefore, it seems unlikely that the adults pass the winter in the state of reproductive diapause in this species. Our results show that *P. sita* overwinters as larvae or pupae and emerges as adults in spring at Esuzaki and Yamada. Since pupae of the overwintering generation were seen until late March and early May in Esuzaki and Yamada, respectively, adult emergence are inferred to occur between mid April and early May and between mid May and early June in the former and latter habitats, respectively.

Seasonal occurrence at 3 habitats

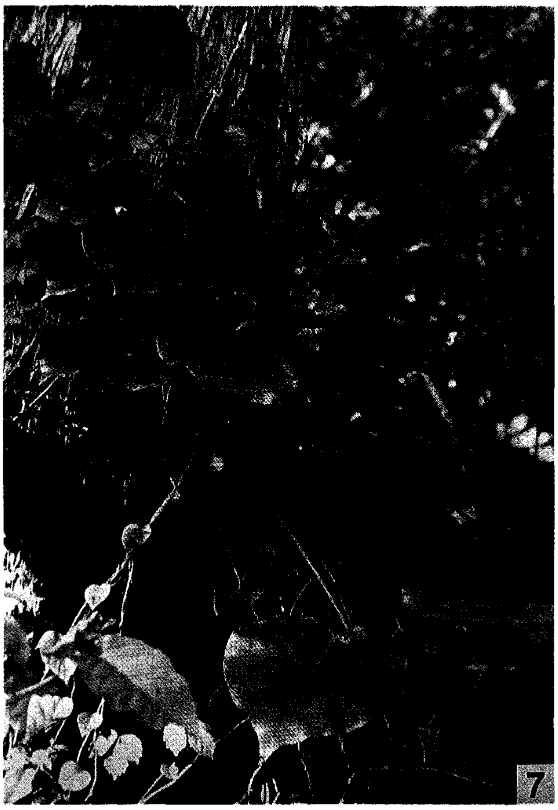
In general, ovaries of the insects that migrate long distances are immature at the adult emergence, and they stop the migration when their ovaries mature (Johnson, 1969). Although Fukuda (1989) inferred that ovaries of this species develop rapidly between one and two weeks after emergence under a photoperiod of 13L-11D at 25°C, results of our experiments show that it takes 2 weeks for a half of females to mature eggs even at a high temperature of 25 and 20°C, respectively, in *P. sita*. Therefore, it is possible that *P. sita* migrates a few weeks before oviposition.

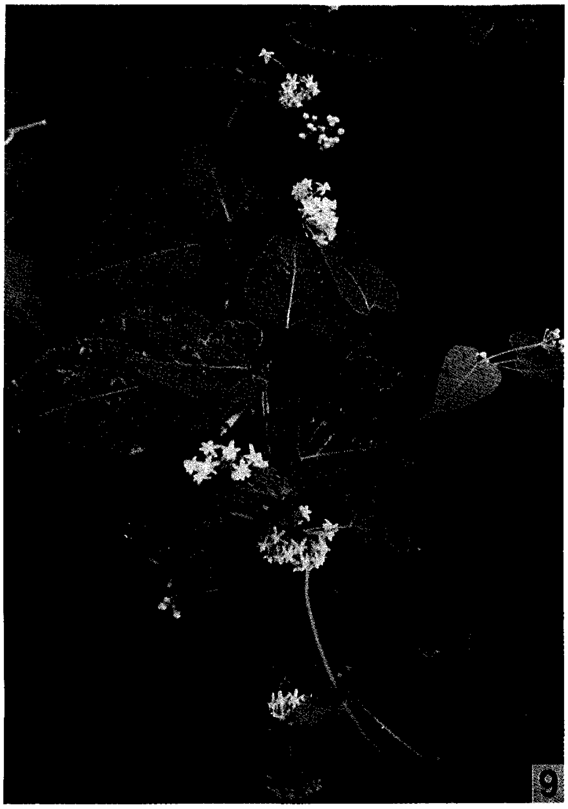
According to the corrected temperature from AMeDAS, t_0, K, and results that about 2 weeks are needed for a half of female to mature after adult emergence, we inferred the life cycles of *P. sita* at the 3 habitats, Esuzaki, Yamada and Mt Wasamata (Fig. 12). We supposed the adult emergence of overwintering generation as April 1, April 15 and May 1, May 1, May 15 and June 1, May 1, June 1 and July 1, at Esuzaki, Yamada and Mt Wasamata, respectively.

Although *P. sita* passes 3–4 generations from spring to autumn at Esuzaki in our estimation, there was a long blank, from May to August, in which no individual of immature stages was seen there. It is likely that adult *P. sita* of the overwintering generation emigrated from Esuzaki without oviposition in spring.

At Yamada, 3–4 generations are expected to occur, including the overwintering generation. However, we observed eggs, larvae and/or pupae continuously all the year round at Yamada, so that we could not measure the number of generations there. Although we observed a few adults at Yamada, Chestnut-Tiger Research Group (1986*a, b*) reported that no adults were seen in the Inunaki valley and Mt Tenjin, located near Yamada. Yamada is, therefore, considered one of typical habitats where *P. sita* uses all the year round.

At Mt Wasamata, eggs were first found on *C. caudatum* in early June and late May in 1994 and 1995, respectively, when adults were first seen in each year. Fukuda (1991) suggested that most adults seen at high altitudes in summer were of the generation after the overwintering one (*i. e.* the 1st generation). Our observation at Mt Wasamata seems not inconsistent with Fukuda's suggestion, although we have not observed if the adults emerged in the vicinity





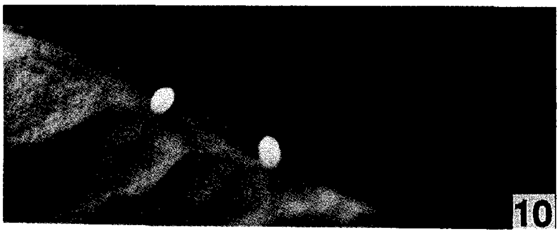


Fig. 7. The evergreen milkweed, *Marsdenia tomentosa*, climbing up the Japanese cedar at the study site of Yamada.

Fig. 8. Two 5th (final) instar larvae on a leaf of the evergreen milkweed, *Marsdenia tomentosa*, at the study site of Esuzaki.

Fig. 9. A deciduous milkweed, *Cynanchum caudatum*, seen at the study site of Mt Wasamata.

Fig. 10. Two eggs on a leaf of *Cynanchum caudatum*, at the study site of Mt Wasamata.

Fig. 11. A male adult of *P. sita* visiting the thoroughwort, *Eupatorium makinoi*, at Mt Wasamata.

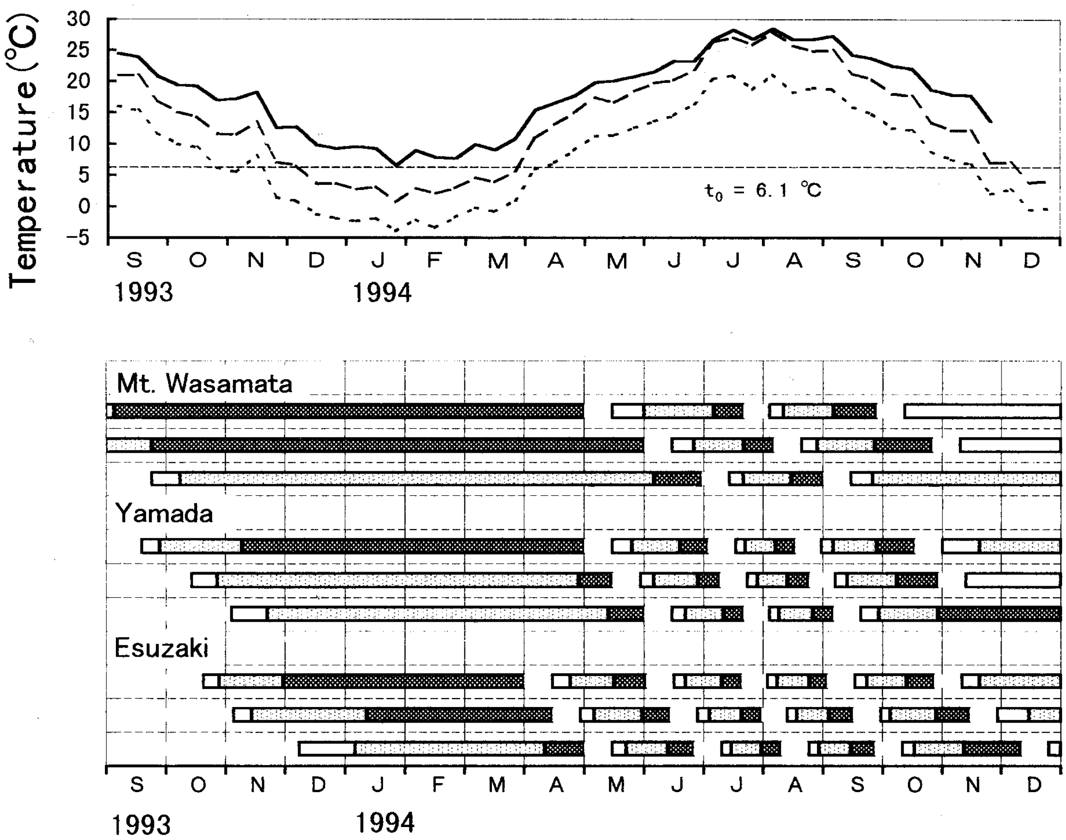


Fig. 12. Seasonal changes in mean temperatures of 3 habitats. Esuzaki ——, Yamada - - - - and Mt Wasamata - - - -, and estimated seasonal cycles of *P. sita* at the 3 habitats inferred from results of rearing experiment. □, egg ; ▒, larva ; ▩, pupa.

or immigrated from other places.

Fukuda (1991) also suggested that adults that migrate to the south in autumn are mainly of the 1st or the 2nd generations, and he assumed that they migrate at first from highlands to lowlands and then toward the southwest along the coast of the Pacific Ocean. In fact, densities of eggs and early instar larvae from late autumn to early winter were more than 2 times larger in Esuzaki than in Yamada. The results may show that Esuzaki, located on the Pacific coast, is on the routes of autumnal migration of *P. sita*, although it is unclear if the site is one of the terminals of migration.

Thus it was impossible to estimate the numbers of generations at each habitat from the effective accumulative temperature. This may be because of the highly migratory nature in this species. To examine the significance of their migration is a problem for future study.

Acknowledgements

We express sincere thanks to Mr F. Ito of the Lepidopterological Society of Japan and members of the Chestnut-Tiger Research Group for their kind advise. Our thanks are also due to Dr T. Hirowatari and other members of the Entomological Laboratory of Osaka Prefecture University for their kind advise and assistances.

References

Barker, J. F. and W. S. Herman, 1976. Effect of photoperiod and temperature on reproduction of the Monarch butterfly, *Danaus plexippus*. *J. Insect Phisiol*. **22**: 1565–1568.

Chestnut-Tiger Research Group, 1986*a*. A report in researches of larvae of *Parantica sita* at Inunaki Valley in Osaka Prefecture. *Nature Study* **32** (8): 4–6 (in Japanese).

———, 1986*b*. Researches for oviposition of *Parantica sita* at Yogi-yama (Mt. Tenjin) in Nara Prefecture. *Nature Study* **32** (6): 4–6 (in Japanese).

Fukuda, H., 1989. Female internal genitalia and egg maturities of *Parantica sita* (Danaidae, Lepidoptera). *Bull. Kagoshima Mus*. (**8**): 1–6 (in (in Japanese).

———, 1991. Seasonal migration of the chestnut tiger, *Parantica sita* in Japan. *Insectarium* **28** (12): 4–13 (in Japanese).

Johnson, C. G., 1969. *Migration & Dispersal of Insects by Flight*. 763 pp. Methuen, Bungay, Suffork.

Kanasawa, I., Okuno, S., Takemoto, T., Miyatake, Y., Hosoi, T. and M. Ohtsuki, 1993. Bionomics of the Chestnut Tiger, *Parantica sita* (Lepidoptera, Danaidae) in the western part of Japan—Results of researches from 1983 to 1989 by The Chestnut Tiger Research Group. *Bull. Osaka Mus. nat. Hist*. **47**: 47–59.

Watanabe, K. and Y. Jinbo, 1968. Overwintering of the chestnut tiger, *Parantica sita*. *Suruga no Kontyu* (62): 1755–1757 (in Japanese).

摘　　要

紀伊半島の3地点におけるアサギマダラの季節消長（平井規央・石井実）

アサギマダラ *Prantica sita* を15, 20, 25°Cの12時間および16時間日長の6条件で飼育したところ，卵，幼虫，蛹のどの発育段階でも休眠は認められず，25, 20, 15°Cにおける平均卵期間はそれぞれ，約5, 7, 12日，同様に平均幼虫期間は約18, 23, 40日，平均蛹期間は約10, 15, 27日であった．また，飼育実験により得られた雌成虫は，25°Cでも羽化後半数の個体が成熟卵を持つようになるまで，2週間前後を要した．

さらに野外での本種の季節消長を知るために，海岸線近くの生息地として江須崎（和歌山県すさみ町，標高約20 m），低山地の生息地として山田（和歌山県橋本市，標高約360 m），および高山の生息地として和佐又山（奈良県上北山村，調査地点の標高約1,100 m）の紀伊半島に位置する3地点を選び，卵，幼虫，蛹，成虫の密度調査をおこなった．その結果，江須崎は主として本種の越冬地として利用されており，冬季には多数の幼虫が見られたが，夏期には本種の卵-蛹が見られない時期があった．山田では，越冬世代の他，夏の間も少ないながら卵，幼虫，蛹が確認された．両調査地ともに，10-11月に卵が増加したが，密度は江須崎の方が高かった．和佐又山では，6月から9月にかけて成虫が見られ，7-8月にピークが認められた．また，持ち込んだキジョランには卵と3齢幼虫が，自生の落葉性のイケマ（ガガイモ科）でも卵および3齢以下の若齢幼虫がそれぞれ認められた．

飼育結果と気温から，各調査地での本種の世代数を推定したところ，春から秋にかけての世代数は実際の野外調査の結果と完全には合致しなかった．これは本種の高い移動性によるものと考えられる．

(Accepted May 26, 1997)

Published by the Lepidopterological Society of Japan,
c/o Ogata Building, 2-17, Imabashi 3-chome, Chuo-ku, Osaka, 541 Japan